Unmanned Vehicles and the Tactical Control System for the DD 21

Dr. Ronald S. Peterson

The ongoing Naval Surface Warfare Center, Dahlgren Division (NSWCDD) Dahlgren Laboratory's development of the innovative Tactical Control System (TCS) for unmanned aerial vehicles (UAVs), and the recent NSWCDD Coastal Systems Station (CSS) demonstration of TCS for unmanned maritime and ground vehicles have enabled exciting opportunities to introduce cost-effective, unmanned systems technology into the DD 21 and other 21st century naval surface combatants. These ships must depart radically from current designs in the future warfare environment, with unprecedented emphasis on littoral warfare missions, joint and allied battlespace awareness, reduced manning and life-cycle costs, and intolerance to casualties. For the DD 21 and other future surface combatants, investigators at CSS are considering a family of small, organic, and offboard unmanned vehicles operating under the TCS for cost-effective command, control, communications, computers, and intelligence (C4I)-connectivity and joint interoperability, and for conducting a broad range of ship self-protection, land attack, and other littoral warfare missions.

Introduction

The DD 21 Land Attack Destroyer and other U.S. Navy surface combatant ships of the 21st century must depart radically from current designs and operating methods. The shift in strategy includes emphasis on littoral warfare missions, joint and allied battlespace awareness, optimized crewing, reduced life-cycle costs, unsurpassed survivability, and reduced tolerance to casualties. These fundamental and sometimes conflicting requirements present a daunting challenge to the research and development (R&D) community within the U.S. Navy and industry. Recent and ongoing developments at NSWCDD Dahlgren Laboratory and CSS in unmanned vehicles and vehicle control systems are in direct response to this challenge. The Dahlgren Laboratory has served a central role in the development of the innovative TCS for UAVs. CSS has extended the application of TCS into a full spectrum of unmanned vehicles, including unmanned maritime vehicles (UMVs) and unmanned bottom and ground-crawling vehicles (UGVs). CSS is exploring the concept of integrating into 21st century combatants a family of small, cost-effective, organic, and offboard unmanned vehicles operating under TCS. These unmanned systems will conduct a broad mix of reconnaissance, surveillance, ship self-protection, land attack, and other littoral warfare functions, with emphasis on deployability and reduced cost, C4I-connectivity and joint interoperability, and minimal threat to life.

This article describes the TCS for UAV, the extension and demonstration of TCS for a growing family of unmanned vehicles performing littoral warfare functions, and a revolutionary concept for the DD 21 and other future combatants performing ship self-protection and land attack missions with TCS-controlled unmanned vehicles.

THE ENABLING TECHNOLOGY—TCS FOR UAV

TCS grew out of the need for a common control architecture for UAV. The UAV-TCS Program was launched in 1996 and is sponsored by the Program Executive Office (PEO) for Cruise Missiles and UAVs. The software engineering agent for TCS is the Dahlgren Laboratory. TCS provides UAV operators with a common, scalable, C4I-connected, and joint interoperable control system that provides real-time data receipt and dissemination to multiple command authorities, avoiding the traditional and expensive stovepipe approach to UAV C4I interfacing and vehicle control. TCS may be hosted on each of the computer platforms in use by the Navy, Marine Corps, Army, and Air Force. Approximately 200 surface ship, ground, and airborne joint-service platforms—including approximately 100 Navy ships—are targeted for TCS installation.

An important feature of TCS is scalability. TCS is being developed for operation at five levels of capability:

- Level I is secondary imagery and data receipt, display, and dissemination
- Level II is direct imagery and data receipt, display, and dissemination
- Level III adds payload control capability to that of Level II
- Level IV adds vehicle control capability to that of Level III
- Level V (in development) will add vehicle launch and recovery capability to that of Level IV

Level II receipt, display, and dissemination of imagery might be performed on a small portable computer carried by a special operations forces unit in the field. Level IV capability, with vehicle and payload control, would be installed, for example, on board a surface combatant.

Also central to the TCS concept is the small "personality module," or Datalink Control Module (DCM), that interfaces each UAV with the core TCS system. The vast majority (nominally 98%) of the TCS software will be common among the various TCS installations. The common TCS core software and C4I interface components may thus be readily modified with one software upgrade for all of the TCS installations as the need arises.

TCS is not only a vision, but an evolving reality. UAV demonstrations of TCS over the past two years have included:

- Level I data receipt and dissemination with the vertical-takeoff Tactical UAV Eagle Eye and Bombardier CL-327
- Level II data receipt and dissemination with the Tactical UAV Outrider and Pioneer
- Level II data receipt and dissemination with the Medium-Altitude/Endurance UAV Predator
- Level IV control of the Medium-Altitude/ Endurance UAV GNAT 750 and, most recently
- Level IV control of the General Atomics Tactical UAV Prowler

TCS FOR UMVS AND UGVS

The CSS mission is to develop for the U.S. Navy and joint services advanced warfighting systems for the coastal, or littoral region. Principal examples of CSS's littoral warfare R&D areas are mine warfare, naval special warfare, and amphibious warfare. Performance of these missions involves advanced sensor technology; towed, tethered, and

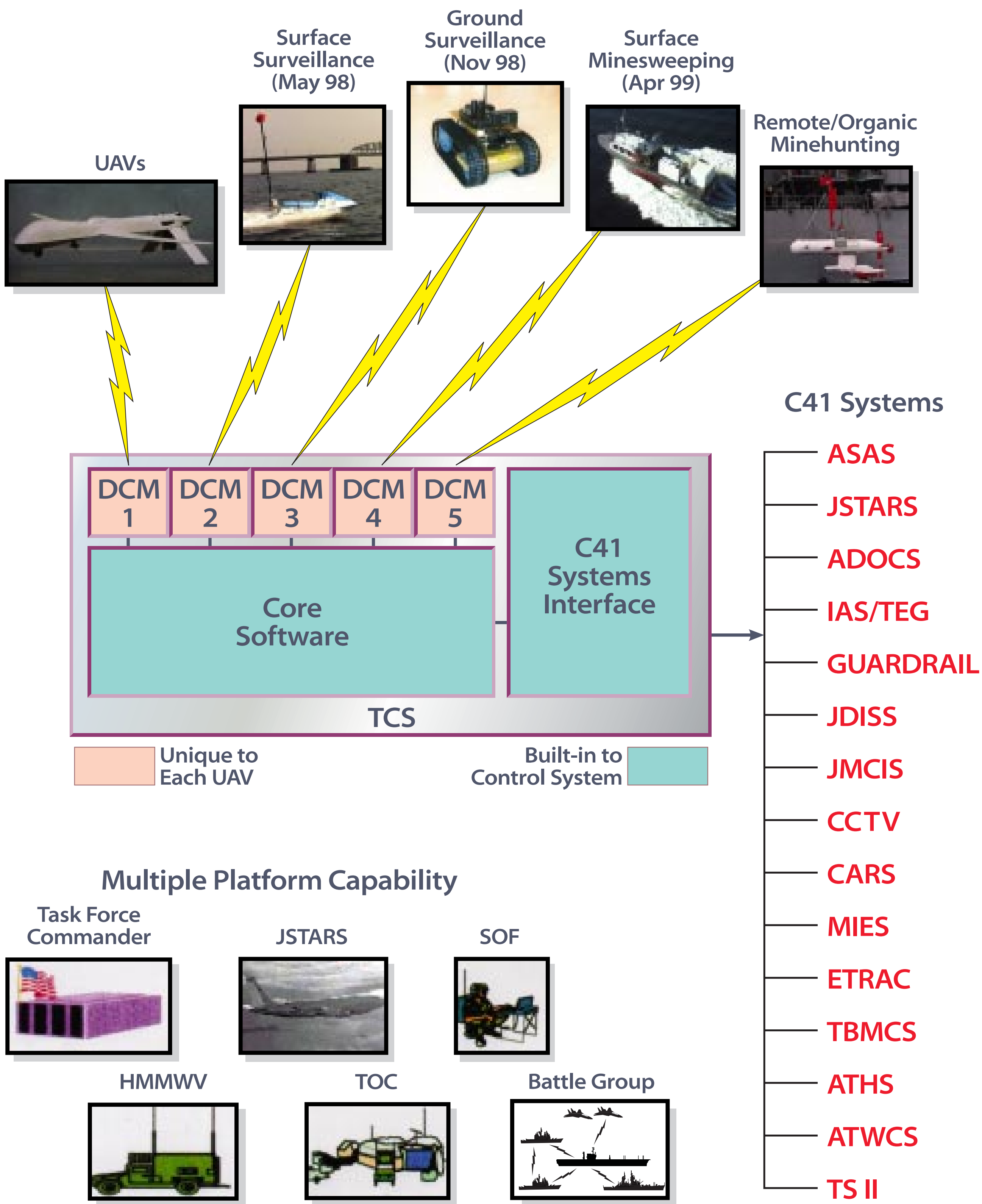

Figure 1—TCS Architecture and Unmanned UAVs, UMVs, and UGVs

self-propelled maritime vehicles; and increasingly, unmanned vehicles. CSS is a leader in underwater sensors, including superconducting magnetic gradiometers, laser line-scan systems, synthetic aperture sonars, and advanced signal processing technology. The UAV-TCS project facilitated the CSS extension of TCS into the maritime and littoral warfare environment. CSS began a highly successful partnership with the Dahlgren Laboratory in 1997 to demonstrate the integration of TCS, littoral warfare, and a broad spectrum of unmanned vehicles. This vision—showing UAVs, UMVs, UGVs, and their relationship to TCS—is illustrated in Figure 1.

The introduction of a particular unmanned vehicle to the TCS-equipped platform only requires installing the small specific DCM and bringing the actual vehicle on board. The approach eliminates the expensive development of either a dedicated control system for each new vehicle, or a new C4I interface for each control system. While the current version of TCS is capable of controlling up to two vehicles, ultimately, the architecture will support the installation of multiple vehicle-specific DCMs, each capable of controlling a number of the specific type of vehicles. The number of vehicles that may be supported by a particular TCS installation will, however, be limited by operator workload and display constraints.

LITTORAL WARFARE MISSIONS AND UNMANNED VEHICLES

CSS has considered an exciting spectrum of important littoral warfare missions for unmanned maritime and ground vehicles. Possible video and infrared surveillance and reconnaissance functions include ship identification, and bridge and harbor surveillance of enemy troop, convoy, and ship movements. Fire support missions include close-in identification of fixed and mobile targets, precision target designation, weapons delivery, and poststrike battle damage assessment. Candidate rescue missions include downed-pilot rescue and special operations forces' extraction in high-threat coastal areas. Unmanned vehicles could perform ahead-of-ship mine reconnaissance, antisubmarine and antisurface ship warfare, and could provide early warning against small, high-speed gunboats and missiles. High-value U.S. submarines and surface combatants may remain at a safe standoff distance from shore while the UMV patrols the shallow water for Third-World diesel subs and enemy surface craft. Small and inexpensive UMVs and UGVs could be equipped with explosives and dispatched to coastal and harbor areas to target enemy artillery emplacements and surface craft. Unmanned vehicles could support long standoff electronic warfare with radio-frequency surveillance, jammers, and decoy systems to disrupt communications. Unmanned vehicles are also ideal platforms for conducting clandestine and semiclandestine tactical oceanography in support of an amphibious landing. Central to the conduct of these missions with TCS is the battlespace awareness afforded by its broad C4I connectivity and joint interoperability between the various U.S. and Allied services.

The Office of Naval Research recently launched a program involving CSS, other Navy labs, and industry and academic participants, to develop the technologies for enabling small unmanned vehicles to conduct mine reconnaissance and neutralization in the very shallow water and surf zone. The goal is to initially supplement—and eventually replace—the mammals and human divers who are currently responsible for this extremely hazardous mission. Inherent within the concept is the operation of a large number of small, inexpensive, and cooperating unmanned underwater swimming and bottom-crawling vehicles. Required technology development areas include multivehicle underwater navigation techniques and underwater communication with sufficient range and bandwidth. TCS is a candidate for controlling the "swarm" of vehicles. CSS is thus investigating the application of TCS, currently capable of radio-frequency control of two vehicles, to control a large number of underwater vehicles.

ROBOSKI-TCS DEMONSTRATION

To prove the UMV-TCS concept, CSS assembled a TCS control center, borrowed the small UMV known as RoboSki, developed a RoboSki DCM, and demonstrated the RoboSki-TCS system performing surveillance and reconnaissance missions in the local CSS waters. The heart of the TCS control center is a rack-mounted “dual-eye” TAC-4 Navy computer that hosts the TCS core software and DCM. RoboSki, a small personal watercraft modified by RoboTek, Inc., for unmanned operation, was developed originally as a remotely operated target for destroyer live-fire gun practice. RoboSki development was initiated and partially funded by the U.S. Navy’s Naval Science Assistance Program, with the Naval Facilities Engineering Service Center in the role of technical development agent.

CSS demonstrated TCS control of RoboSki performing coastal surveillance and reconnaissance missions in mid-1998, as shown in Figure 2. The UMV was equipped with the Global Positioning System (GPS); a four-quadrant, black-and-white video system; and a line-of-sight radio-frequency link at 440 MHz for control and status, and 2.2 GHz for video. The vehicle track was displayed in real time on the upper TAC-4 map-display monitor, and the four-quadrant video was displayed in real time on the lower payload/imagery monitor. The vehicle was operated from TCS in both remote-control mode and autonomous waypoint mode.

CSS recently purchased a RoboSki to facilitate follow-on TCS development and demonstration in support of additional littoral warfare missions. The vehicle in its current configuration is not necessarily the optimum platform for any particular littoral warfare mission; but because it is capable, inexpensive, and easily reconfigured, it represents an ideal development and demonstration platform. CSS is investigating a wide range of suitable functions for the RoboSki (including those of the DD 21 mission) and plans to equip the vehicle with additional sensors, image stabilization systems, and over-the-horizon datalink capability.

LEMMINGS-TCS DEMONSTRATION

CSS demonstrated a second vehicle—the Lemmings Crawler—operating under TCS in late 1998. This small, amphibious, tracked vehicle was developed by Foster-Miller, Inc. CSS outfitted a “stripped down” Lemmings Crawler with a low-cost video and radio-frequency video link, a control and status radio-frequency link, and differential GPS; they then developed and integrated a Lemmings DCM into the existing CSS TCS software. The vehicle was demonstrated under remote control of TCS—crawling over the beach and various inland areas as shown in Figure 3—with real-time track displaying on the upper TAC-4 map-display monitor and its video displaying on the lower monitor.

UNMANNED VEHICLES AND THE DD 21 LAND ATTACK DESTROYER

The DD 21 is an important example of the future U.S. naval surface combatant, whose primary mission is land attack warfare—while minimizing vulnerability to attack. With a projected date for initial operational capability of 2008, the DD 21 is being developed with extreme emphasis on optimized crewing, advanced automation, reduced life-cycle costs, off-the-shelf technology, and joint U.S. and Allied interoperability and battlespace awareness. Candidate advanced land attack weapon systems for the DD 21 are missile systems such as the Advanced Land Attack Missile and Tactical Tomahawk, and an Advanced Gun System with Extended Range Guided Munition. Laser-guided terminal homing systems are also being considered for the DD 21 by industry. CSS investigators are considering two unmanned systems functions for the DD 21 and other 21st century naval surface combatants: ship self-protection and precision land attack support.

Ship Self-Protection

The DD 21 ship self-protection function would include ahead-of-ship and perimeter defense, which would be achieved with small, ship-deployed, TCS-controlled surface-planing or semisubmerged UMVs. Unmanned surface craft could function as high-speed scouts, patrolling ahead or in the perimeter of the ship or task force while the ships are at anchor or underway. A small, side-scan sonar, for example, could be remotely deployed from a UMV for performing ahead-of-ship mine reconnaissance.

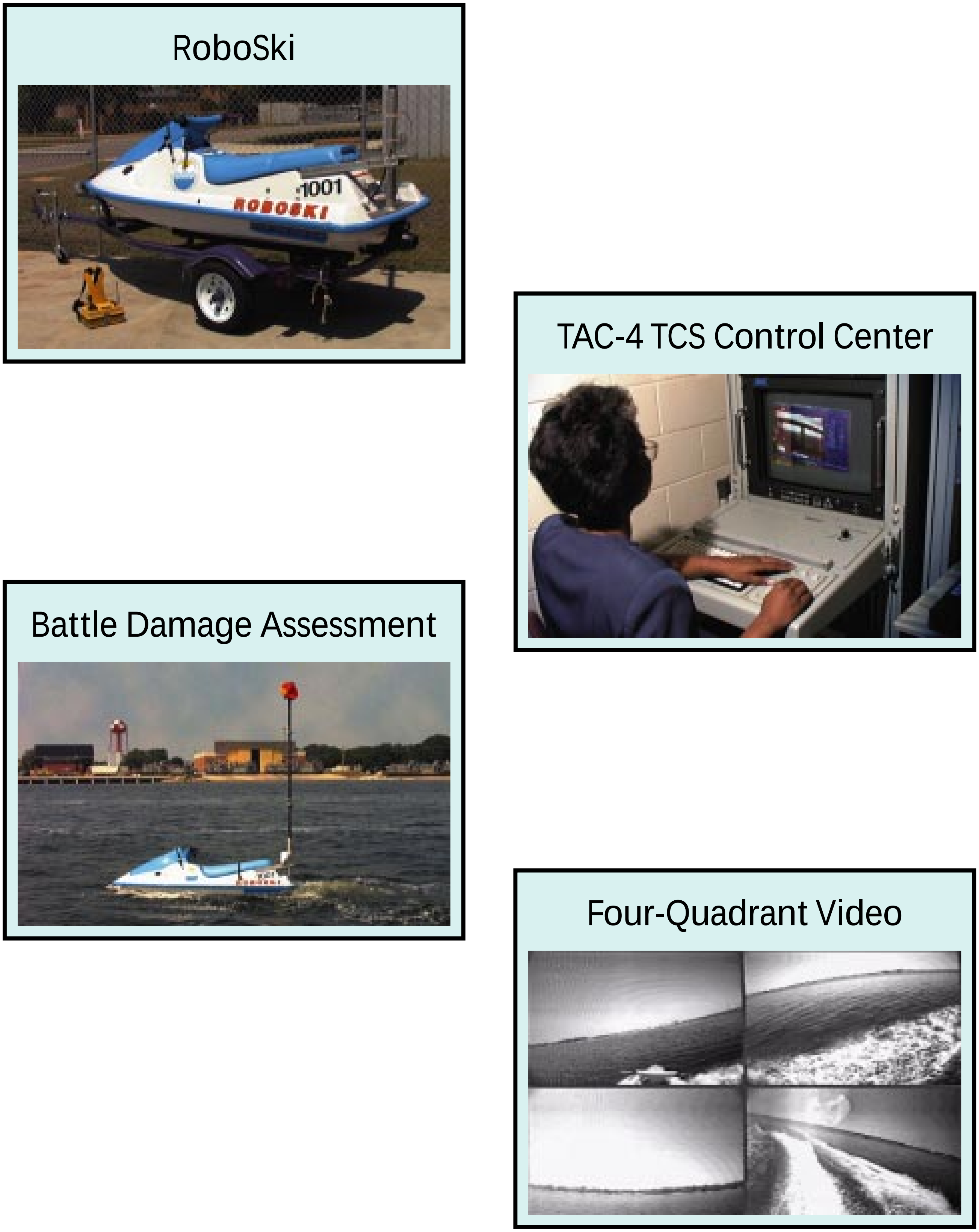

Figure 2—RoboSki Performing Surveillance and Reconnaissance Missions Under TCS Control

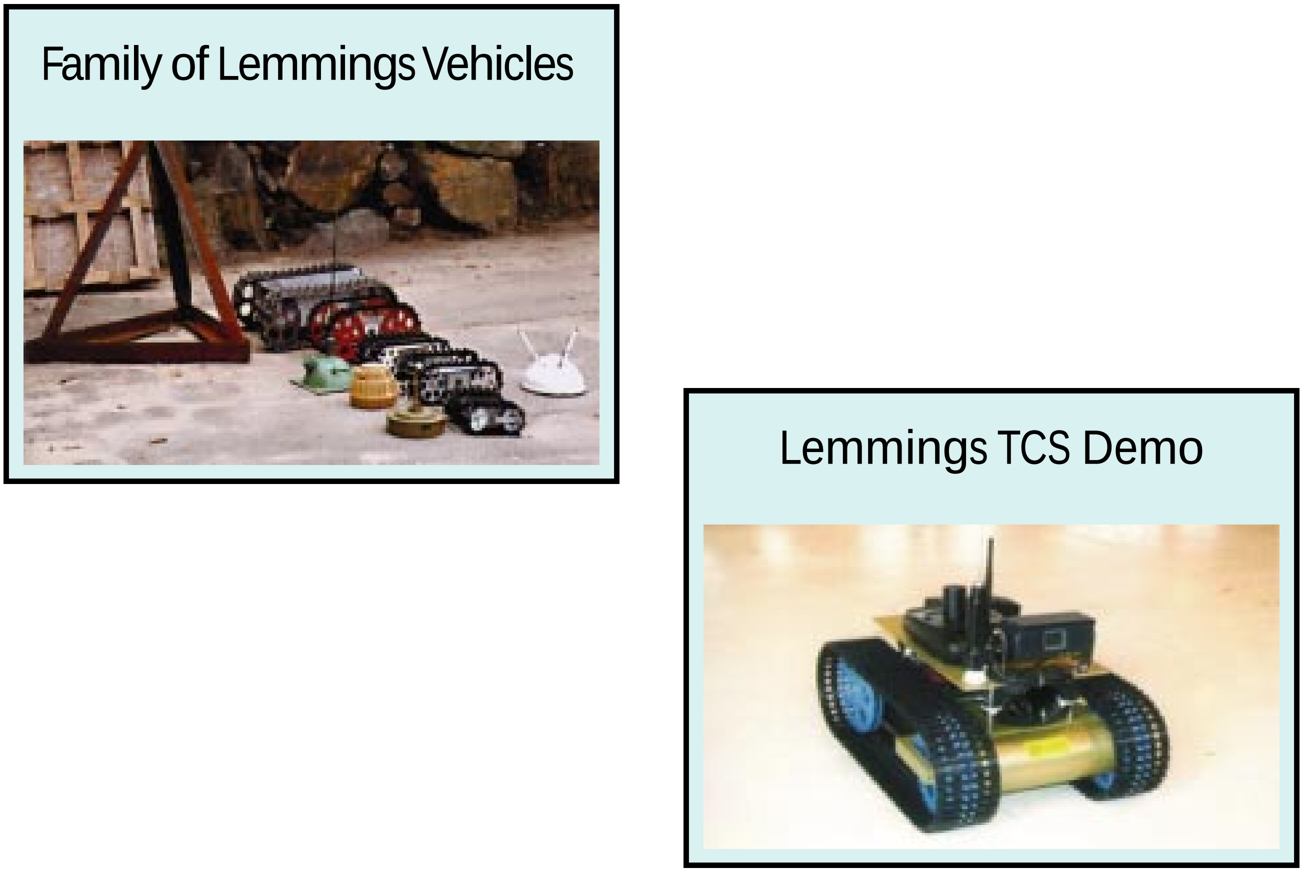

Figure 3—The Lemmings Crawler and Lemmings Family

A long-range sonar such as the CSS Toroidal Volume Search Sonar could be used for detection of Third-World diesel-electric submarines. The scouts could be equipped with a missile decoy or jamming system in the event of missile attack, or with a laser-designator for use against enemy surface craft at anchor or underway. The scouts would be especially useful in a confined and dangerous bay or harbor where a distant fishing vessel, presumed to be friendly, may in fact be a heavily armed threat; or where small, high-speed gunboats with a low radar cross section could pose a serious threat. Remote perimeter reconnaissance and surveillance would provide early warning and an extra margin of safety for these ships in such hazardous environments.

Preassault Precision Land Attack Support

The DD 21 unmanned, preassault, precision land attack function would be conducted at night with a mix of TCS-operated vehicles, including a UAV and a number of surface or semisubmerged UMVs and UGV crawlers, as illustrated in Figure 4. The goal is to support the surface combatant during the land attack mission of achieving coastal, ground, and air dominance prior to an amphibious landing. Specifically, the unmanned vehicles would perform precision target identification and designation, and could themselves destroy targets in the coastal area with onboard munitions. Targets might include enemy patrol craft underway or anchored in a harbor, coastal artillery batteries, personnel bunkers, mobile surface-to-air missile sites, chemical and biological production sites, and command and communication centers. The surface combatant and unmanned vehicle host platform would remain positioned a safe distance offshore, perhaps 50 miles.

A vertical-take-off or fixed-wing UAV patrols the coastal area providing pre- and post-strike airborne surveillance and reconnaissance, as well as an over-the-horizon data link to support the surface and ground vehicles. The UAV could be equipped with video, an infrared imager, and/or synthetic-aperture radar. The UAV over-the-horizon datalink enables the surface combatant to remain far offshore, and provides high-bandwidth communication between the ship and the unmanned vehicles, reducing the requirement for the small vehicles to carry large and expensive antennas. The UMVs are equipped with video, an infrared imager, and laser target designators. Each UMV also carries a number of small, expendable, amphibious UGVs that might also be equipped with video, infrared device, a laser designator, and/or small explosive device.

The UMV and UGVs are deployed from the surface combatant (or could be carried part of the way to the beach with a helicopter) under cover of darkness, and then transit to the beach area where the amphibious UGVs are deployed from the UMV. The UGVs then progress over the beach and inland towards nearby land targets. The UMV continue along the coastline to provide targeting data against ships and installations in the harbor and coastal region. For the target identification function, the UMV and UGVs could provide close-in, detailed high-resolution targeting information in support of precision-guided weapons on board the surface

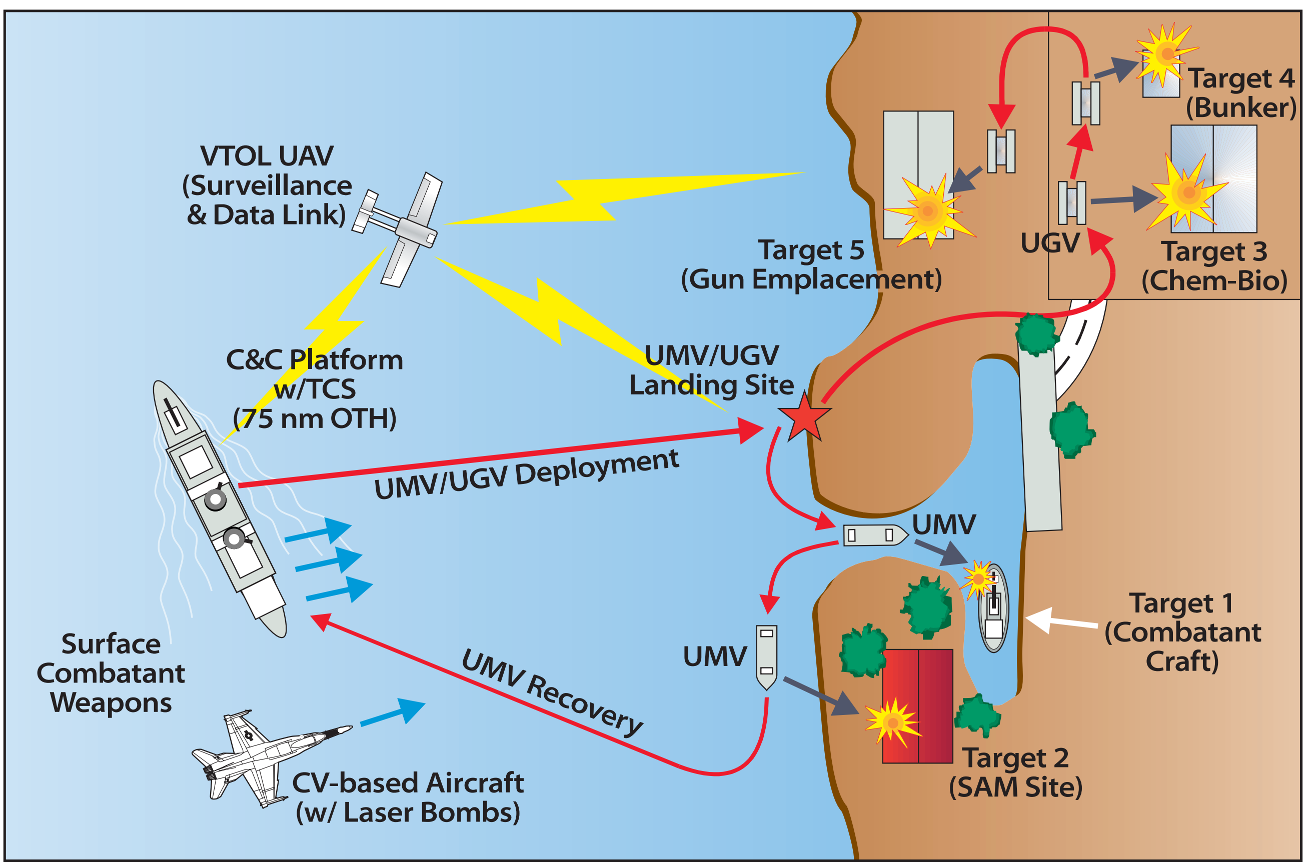

Figure 4—Preassault Precision Land Attack Support with TCS and Unmanned Vehicles

combatants. The UMV and UGV also provide close-in, precise laser designation in support of laser-guided weapons on board the surface combatants or carrier-launched strike aircraft. The UAV and the UMV also provide battle damage assessment following each call for fire and, with GPS data, provide precision spotter adjustments for naval gunfire support. Throughout the mission, real-time imagery, vehicle status, and track data is displayed on the monitors of the TCS station on board the host control platform and on other TCS installations within the battlespace environment.

Fundamental characteristics and advantages of the proposed unmanned strike support mission are close-in, precision, all-weather, 24-hour, high-resolution target identification, target designation, and munitions deployment. For the target identification role, the vehicles could be equipped with thermal, seismic, and acoustic sensors providing the benefits of sensor fusion (capable, for example, of distinguishing between heated/occupied structures and those that are not). For the laser-designation role, all-weather 24-hour precision targeting is achieved with minimal reliance on satellite communications, satellite-based targeting systems, and overhead sensors. For either role, the unmanned vehicles may follow a mobile land or seaborne target, or hold a stationary position, allowing detailed analysis (i.e., “stare and dwell”) of a particular target. The vehicles also provide increased targeting capability against targets that are camouflaged or hidden under foliage, fog, or clouds. For the munitions delivery role, the UGVs, and possibly the UMV, could precisely position small charges for maximum effect with minimum munitions.

The technology for the proposed land attack support mission exists. In a sense, the unmanned approach to precision targeting and land attack support is “low-tech,” since there is less reliance on wideband satellite communication and complex algorithms to achieve improved accuracy with weapons guided with the GPS. The technology areas where development would most benefit the proposed unmanned missions are small and low-cost sensors; sensor fusion; wideband, long-range, and secure communication; and unmanned platform stealth.

SUMMARY

The Dahlgren Laboratory development of TCS for UAV and the recent CSS demonstration of TCS for maritime and ground vehicles have enabled exciting opportunities in the joint littoral warfare environment. CSS investigators are committed to integrating this technology into the 21st century naval surface combatants. Organic and offboard unmanned systems will reduce our future ship’s dependence on mission-dedicated platforms such as MCM ships, ultimately lessening the negative impact of mandated further reduction in the number of ships within the U.S. Navy. The use of unmanned vehicles for ship self-protection and precision land attack support will enhance both the survivability of our surface combatants and the performance of their land attack functions, while minimizing threat to life. The use of TCS for controlling the vehicles will minimize onboard crewing, training, and maintenance requirements and provide improved joint battlespace awareness through its joint interoperability and C4I connectivity.

The Dahlgren Laboratory possesses many years of experience and unsurpassed expertise in UAV technology, radio-frequency communication, strike warfare, and the TCS; CSS possesses comparable experience and expertise in littoral warfare, unmanned maritime vehicles, and underwater sensors. The ongoing and planned future efforts of these two Navy labs to introduce unmanned systems technology into the Navy of tomorrow represents an outstanding example of highly leveraged teaming in support of U.S. Navy maritime dominance in the 21st century.

THE AUTHOR

DR. RONALD S. PETERSON

Dr. Ronald S. Peterson earned his B.S., M.S., and Ph.D. degrees in mechanical engineering from Virginia Tech. He has worked at CSS since 1976, specializing in marine vehicle research and development. He served as head of the CSS Hydromechanics Branch from 1983 to 1988. He is currently serving as head of the Unmanned Systems Project Office. Primary areas of research, development, and project leadership have included: marine vehicle system integration; vehicle propulsion, dynamics, and control; surface-ship wake research; cable dynamics; planing boat water-impact phenomena and reduction of shock and injury; and remote/autonomous vehicle control. He has served as the U.S. Navy's lead hydrodynamicist for Swimmer Delivery Vehicles since 1980. He has extensive experience with towed, tethered, and self-propelled vehicles; and with underwater, semisubmersible, and surface planing and displacement craft. He is a member of the Society of Naval Architects and Marine Engineers, the Precision Strike Association, and the Association for Unmanned Vehicle Systems International. Dr. Peterson has presented papers at 10 major conferences, published 9 journal articles, and authored 39 CSS laboratory reports. He holds one patent, with four additional patents pending.